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AN EXPERIMENTAL INVESTIGATION OF PERFORMANCE AND POLLUTION LEVELS ON DI DIESEL ENGINE WITH WASTE FRIED COOKING OIL AND ITS BIO DIESEL

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ABSTRACT

Alternative fuels research had geared up nowadays and in this connection any fuel that can replace diesel can be a major breakthrough as diesel is being used in transport as well as agricultural sectors. Vegetable oils are treated as alternative fuels for diesel, the reason being their cetane value is nearer to that of diesel and are of renewable in nature. Used cooking oil was collected from various sources and was tested in a 3.68kW Direct Injection (DI) diesel engine at manufacturer specified injection timing and pressure values of 27^0bTDC and 190 bars. The performance parameters along with pollution levels were investigated and compared with pure diesel operation. Used cooking oil had relatively less volatility as well as more viscosity. These problems can be overcome by obtaining biodiesel through a process known as esterification by treating used cooking oil. Experiments were carried out with used cooking oil and its biodiesel at different operating conditions like normal/room temperature (NT) and preheated temperature (PT). Peak brake thermal efficiency (BTE) and Volumetric efficiency (VE) values were found to be higher for pure diesel operation followed by biodiesel and waste fried vegetable oil(WFVO). Biodiesel operation resulted in lower smoke levels and comparable Nitrogen oxide levels(NO_x)in comparison to diesel operation.

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Original Article

INTRODUCTION

The pollution levels are also growing continuously as the number of vehicles is increasing year by year. Diesel fuel is mainly being used in agriculture as well as transportation sectors. Any new fuel with better emission standards that can replace diesel will help in creating a better environment for mankind. India is mostly depending on imports; hence appropriate substitute for diesel fuel also results in foreign exchange savings.

Alcoholic fuels along with vegetable oils are found to be the appropriate alternatives for diesel. The usage of alcohols in diesel engines was not encouraging as their cetane value was comparatively low and at the same time modification of the engine is to be done for better results. On the other hand vegetable oils are found to be a better option because of their cetane value to be nearer to that of diesel.

Methanol, Ethanol and vegetable oils are found to be suitable substitutes for and are also renewable in nature. The calorific value as well as cetane number (40-45) of vegetable (both edible and non edible) oils are nearer to that of pure diesel. Edible grade oils anyhow cannot be used as fuel in engines due to their cost and demand. In the present study used cooking oil or waste fried vegetable oil (WFVO) samples collected from various sources were utilized for experimentation work.

Various researchers attempted the usage of vegetable oil as a fuel on diesel engine and concluded that performance deteriorated due to their high viscous nature and poly unsaturated character leading to several operational and combustion problems. They have reported reduction in power along with increased emissions [1-4]

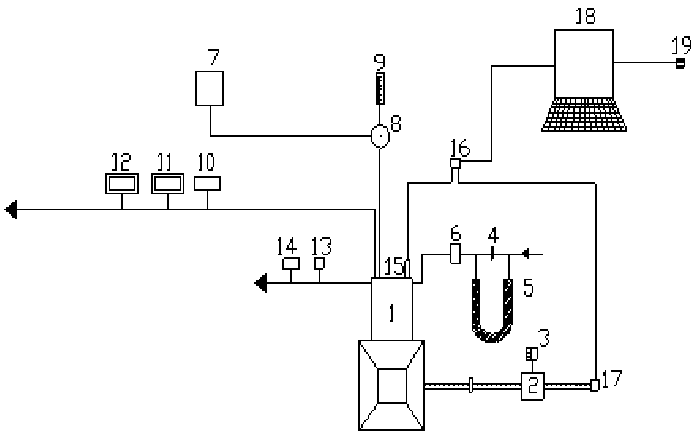
The difficulties associated with the used cooking oil can be overcome to a major extent by obtaining diesel (renewable in nature) through the esterification process. Many researchers conducted experiments on conventional diesel engine (CE) using biodiesel. They reported little improvement regarding performance and particulate matter but Nitrogen oxide (NO_x) levels were observed to increase [5-9].

Studies were carried out on preheated vegetable oils after matching the viscosity to that of neat diesel so that problems associated with injection process were eased. They reported reduction in Nitrogen oxide and smoke levels [10-12]

In the present study experiments were conducted on diesel engine (DI type). Pollution levels and performance parameters were investigated with used cooking oil and its biodiesel, as fuels, at the recommended injection pressure and timing of 190 bar and 27^0bTDC. The results were compared to that of diesel operation.

MATERIALS AND METHODOLOGY

Figure 1, shows the experimental setup used for the conducting experiments with diesel. It is a 4 stroke, Kirloskar make engine having one vertical cylinder. The engine develops 3.68 kW at an RPM of 1500. The diameter and stroke lengths are 80 and 110 millimeters. The combustion chamber was of direct injection type for which water cooling was employed. Electrical dynamometer was employed foe measuring the Brake Power developed by the engine. Exhaust temperatures were measured with the help of thermocouples. Nitrogen oxide levels (NO_x)were measured with an analyser which works on chemiluminescence principle (Netel Chromatograph make)



1. Engine
2. Electrical Dynamometer
3. Load Box
4. Orifice meter
5. U-tube water manometer
6. Air box
7. Diesel tank
8 Three-way valve
9. Burette
10. Exhaust gas temperature indicator
11. AVL Smoke meter
12. Netel Chromatograph NO_x Analyzer
13. Outlet jacket water temperature indicator
14. Outlet jacket water flow meter
15. Piezo-electric pressure transducer
16. Console
17. TDC encoder
18. Pentium Personal Computer
19. Printer.

Figure 1: Experimental Set-Up for Neat Diesel Operation

At various brake mean effective pressures. Smoke levels were recorded with smoke meter of AVL make.

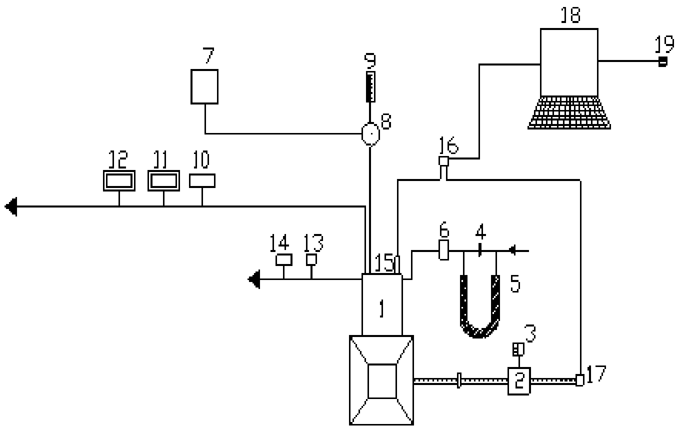
Waste Fried Cooking Oil and Biodiesel Operation on Engine

In the present study the waste fried cooking oil obtained from various sources was used as fuel. The main problem associated with its usage was its high viscosity. If crude vegetable oil was directly used instead of biodiesel it causes several operational problems like deposits formation in injectors, cylinders and fuel lines along with piston ring sticking. Usage of crude vegetable oil also increases emissions and causes reduction in power output. All these things may happen over a certain duration depending upon usage of engine and fuel system design.

Used cooking oil/ waste fried vegetable oil (WFVO)was converted into biodiesel (WFBOBD) through a process known as esterification and the properties of these fuels were obtained from M/s I.I.C.T; Hyderabad[21]

Operating Conditions

The experiments were conducted at two different conditions, one is at normal temperature (NT) and the other being at preheated temperature (PT) i.e. the temperature where used cooking oils viscosity was made equal to the viscosity of pure diesel through heating.The fuels used during tests were pure diesel, used cooking oil (WFVO) and its biodiesel (WFVOBD). The terms waste fried vegetable oil and waste fried cooking oil were interchangeably used in this article. Figure 2 shows the experimentation setup employed for used cooking oil and its biodiesel operation.



1. Engine
2. Electrical Dynamometer
3. Load Box
4. Orifice meter
5. U-tube water manometer
6. Air box
7. Vegetable oil tank
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Figure 2: Experimental Set-Up for Cooking Oil / Biodiesel Operation

RESULTS AND DISCUSSIONS

Performance Parameters

The parameters like Volumetric Efficiency (VE), Brake Thermal Efficiency (BTE), Brake Specific Energy Consumption (BSEC)and Exhaust Gas Temperature (EGT) were discussed in this section. Figure 3 shows the bar chart

drawn for studying the variation of brake thermal efficiency of various test fuels in conventional diesel engine (CE). The chat indicates the trend of peak BTE at a pressure of 190 bar and 27^0bTDC injection timing specified by manufacturer. It was observed from the chart that the peak BTE with WFVO in comparison to diesel due to high viscous nature and less energy content of used cooking oil.

From the same bar chart it can be observed that biodiesel operation resulted in 4% reduction of efficiency in comparison to pure diesel operation and this can be attributed to low calorific value and moderate viscous nature of biodiesel

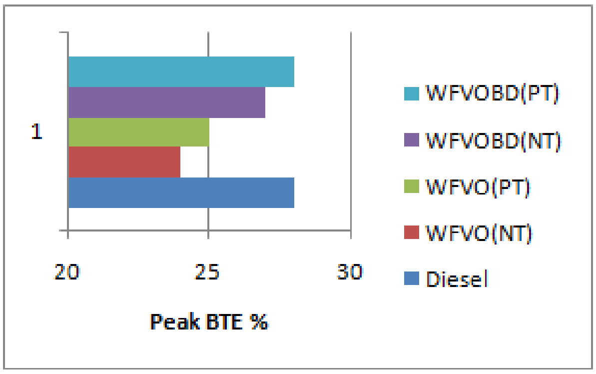

Figure 3: The Variation of Peak Brake Thermal Efficiency (BTE) with Test Fuels

BTE was higher by 8% at recommended injection timing with biodiesel in comparison to used oil operation. This can be attributed to the higher cetane number of biodiesel and oxygen content available in it. Brake thermal efficiency values are observed to be in ascending order for used cooking oil, biodiesel and diesel, the reason being more calorific value and less viscosity of diesel than the other two fuels. Previous researchers reported similar trends [13]

Once preheating was carried out the performance trends were observed to be better with test fuels of WFVO and WFVOBD. Preheating resulted in the reduction of viscosity along with better spray pattern of fuel in the combustion chamber resulting in better efficiency. The rates of heat release for preheated biodiesel was more indicating the predominance of diffusion combustion mode. In case of preheated biodiesel because of evaporation and better intermixing resulted in more heat release rates and consequent complete burning

In general when brake specific energy consumption (BSEC) is lower the performance the engine is considered to be better. At full load operation biodiesel has the comparable BSEC value in comparison with neat diesel operation

Figure 4 shows the variation of BSEC with various test fuels in the form of bar chart. From the graph it can be observed that BSEC at full load increased by 17% for waste fried oil, when compared with neat diesel operation. Crude waste fried oil operation, had higher BSEC because of its more viscosity along with low volatility resulting in poor atomization and hence improper combustion.

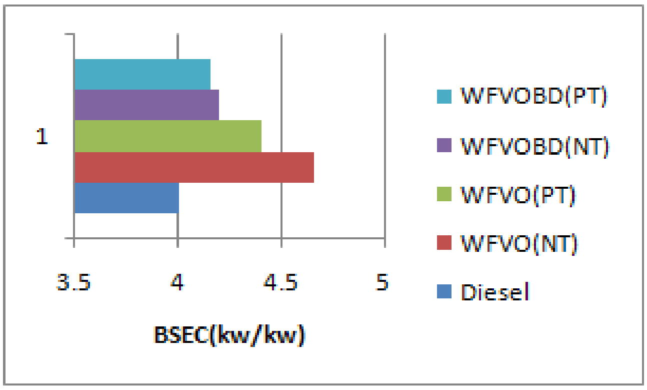

Figure 4: The Variation of Brake Specific Energy Consumption (BSEC) at Full Load Operation

From figure 4 it was observed that BSEC for biodiesel operation was higher by 5% in comparison to pure diesel operation, because of availability of oxygen in biodiesel leading to better combustion. Previous investigators also reported similar trends [15,16]

BSEC values at full load were less by 10% with biodiesel when compared with waste fried oil operation and the main reason being improved combustion of biodiesel due to its higher cetane number along with availability of oxygen in it.

BSEC incase of preheated test fuels was noticed to be less in composition with normal fuels. Preheating resulted in lowering viscosity levels which facilitated better spraying phenomenon. The values of BSEC were observed to be lowest for diesel followed by biodiesel and highest for used cooking oil at 190 bar and 27^{0}bTDC conditions.

Figure 5 shows the variation of exhaust gas temperature (EGT) for the various test fuels under consideration in the form of bar chart at manufacturer specified operating conditions. From this graph, used cooking oil was found to exhibit 22% higher EGT in comparison to diesel operation. The main reason was more combustion duration of waste fried oil due to retarded delay period.

From the Figure 5, it can also be observed that an increase of 13% of EGT for biodiesel when compared to pure diesel operation. Relatively biodiesel operation amounts for more combustion time because of its moderate viscosity. EGT for biodiesel was found to be less by 8% in comparison to used cooking oil because of availability of oxygen in biodiesel inherently, leading to more conversion of heat into work with lower quantities of heat rejection.

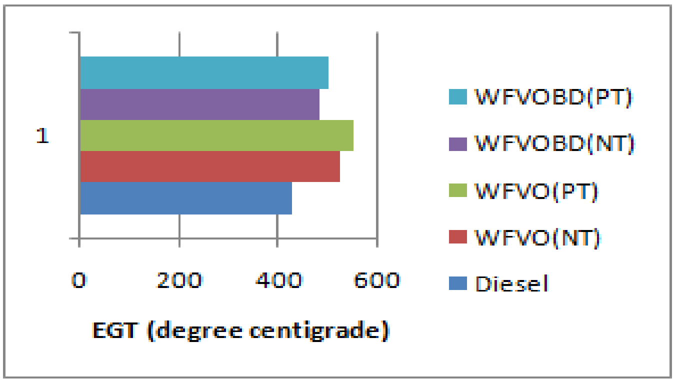

Figure 5: The Variation of Exhaust Gas Temperature (EGT) with Test Fuels in Engine

From Table1, the values of EGT were observed to be increased for test fuels after preheating. This is an indication of diffusion combustion because of better evaporation rates and fuel air mixing. Because of rise in temperature of the fuel, diffusion combustion increased due to reduced delay period leading to rise in values of EGT. Earlier researchers also observed trends of similar nature [14].

The density value of incoming charge, will be effected by wall temperatures of combustion chamber, which in turn effects volumetric efficiency (VE). Figure 6 represents the variation in the volumetric efficiency of test fuels. There was a 6% reduction in VE for used cooking oil operation in comparison to diesel fuel operation, the reason being the accumulation of more quantity of unburnt fuel. Earlier studies also revealed the same trends [13, 17]

The values of Volumetric efficiency were observed to be in ascending order for used cooking oil, biodiesel and diesel. This Was because of better combustion in case of diesel

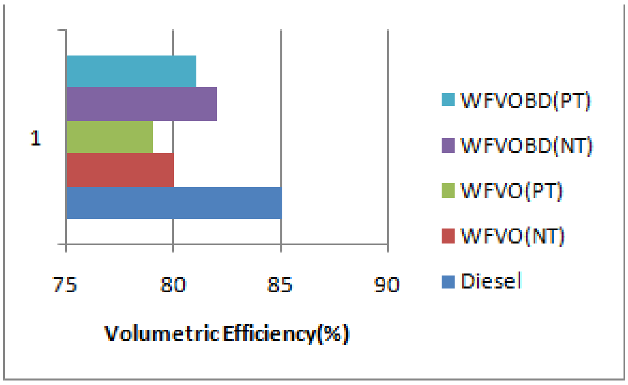

Figure 6: The Variation of Volumetric Efficiency at Full Load with Test Fuels in CE

Due to its higher cetane number. The values of exhaust temperatures were noticed to be less for diesel when compare with other test fuels. Table 1 given below shows the numerical values of all the above performance parameters at recommended injection timings and pressures.

Table 1

	BTE		BSEC		EGT		VE	
	NT	PT	NT	PT	NT	PT	NT	PT
DIESEL	28	-	4.0	-	425	-	85	-
WFVO	24	25	4.66	4.4	520	550	80	79
WFVOBD	27	28	4.2	4.16	480	500	82	81

With preheating values of density and bulk modulus were reduced, which inturn led to marginal decrease in the values of volumetric efficiency, for used cooking oil and biodiesel operation.

Pollution Levels

The pollution parameters like Smoke and Nitrogen oxide (NO_x) levels were discussed here. The same emissions also create severe health issues to human beings. Automobile pollution also reaches water and also leads to acid rains. Therefore controlling of these pollutants is an important issue for well being of society.

Figure 7, shows the bar graph representing the smoke levels variation in the engine for various test fuels represented in Hartridge Smoke Units, HSU. Waste fried oil has shown a rise of 56% in smoke levels when compared with neat diesel operation, the reason being the higher value of C/H ratio for vegetable oil (0.57) where as for diesel it is 0.45.

Smoke levels are directly proportional to the density of the fuel. Because of more density vegetable oil usage generates more smoke during operation. The existence of lingoceric, linoleic, steric and palmic fatty acids in waste fried oil produces more smoke, due to improper fuel air mixing leading to improper combustion. Earlier researchers also quoted similar observations.

Again from Figure 7, it was observed that biodiesel operation reduced smoke levels by 27% in comparison to diesel fuel operation, the reason being oxygen availability in biodiesel. Similarly the CE decreased smoke levels by 53% with biodiesel operation when compared with used cooking oil operation. Because of higher molecular weight of used cooking oil it has got less volatility. Biodiesel viscosity was brought down by removing glycerol molecules through a process known as esterification which also improves volatility. Oxygen content in biodiesel contributed to better interaction between fuel and air. These are all the reasons which resulted in lower smoke generation with biodiesel in comparison to used cooking oil operation.

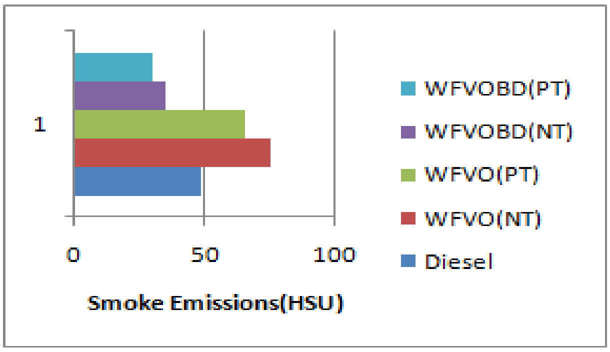

Figure 7: The Variation of Smoke Levels (HSU) with Test Fuels

Smoke levels were observed to be reduced for preheated test fuels in comparison to normal temperature operation. The reasons can be attributed as (a) lowering of density (b) reduced diffusion mode of combustion (c) reduced viscosity levels leading to better spray pattern.

The higher combustion chamber temperatures and oxygen availability are the reasons in formation of higher Nitrogen oxide (NOx) levels. Figure 8, shows the variation of NOx levels in the form of bar chart for various fuels. It was observed that with used cooking oil operation reduced NOx levels by 18% when compared to diesel operation. The reason was lower heat release rates due to more duration of combustion leading to lower values of exhaust temperatures. Earlier investigators also reported this type of trends [5]

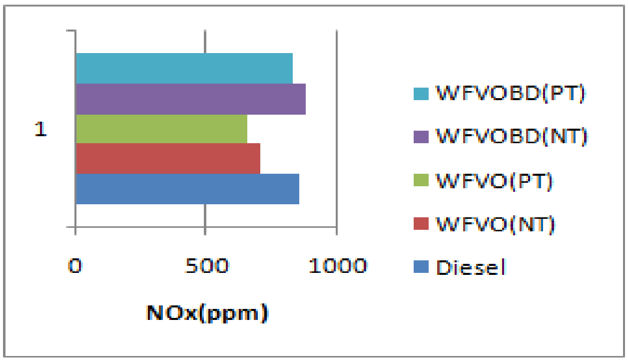

Figure 8: Bar Chart Showing the Variation of Nitrogen Oxide (No_x) Levels at Full Load with Test Fuels in CE

Figure 8 also shows that engine while running with biodiesel exhibited a marginal rise of 3% of NOx levels in comparison to diesel operation. The reason behind this rise can be attributed to the presence of monounsaturated and poly unsaturated fatty acids. Higher nitrogen oxide levels are also due to existence of oleic and linoliec (c18:1 to c18:2) fatty acids[18]. Previous researchers also quoted similar trends [14,19]

From Table 2, it can be observed that nitrogen oxide levels were decreased with preheated version of fuels. Surface tension, viscosity and changes in spray pattern of fuel are the major reasons for reduction of NO_x levels. With rise in temperature of fuel ignition delay gets reduced, leading to lower temperatures which in turn results in lower NO_x formation. Earlier studies also revealed similar trends[14]. The nitrogen oxide levels are observed to be in descending order for biodiesel followed by diesel and used cooking oil. Presence of oxygen in biodiesel is the reason behind more NO_x formation.

Table2 given below shows the numerical values of all the above pollution levels at recommended injection timings and pressures.

Table 2

	Smoke		NO_x	
	NT	PT	NT	PT
DIESEL	48		850	
WFVO	75	65	700	650
WFVOBD	35	30	875	825

CONCLUSIONS

The Conventional DI type diesel engine, biodiesel operation resulted in improvement with reference to performance and smoke levels in comparison to waste fried oil operation, however there was a marginal rise in NO_x levels when compared with waste fried oil operation. It was also observed that preheating led to a reduction in viscosity of test fuels and caused an improvement in performance, but led to marginal increase of EGT values and also reduction in volumetric efficiency.

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